БЕЗОПАСНОСТЬ ДЕЯТЕЛЬНОСТИ ЧЕЛОВЕКА
SAFETY OF HUMAN ACTIVITY

УДК 621.893 10.23947/1992-5980-2017-17-4-122-128

CO_2 emission trend in public energy sector in EU*

E. Niemierka[1], P. Jadwiszczak[2], M. A. Sayegh[3] **
[1,2,3] Wrocław University of Science and Technology, Wrocław, Poland

Тенденция изменения выбросов CO_2 в государственном энергетическом секторе в ЕС***

Э. Ниемерка[1], П. Ядвищак[2], М. А. Саег[3]**
[1,2,3] Вроцлавская политехника, Вроцлав, Польша

Introduction. The EU public electricity and heat production (PEAHP) sector is mainly based on the conventional fuel combustion and is responsible for 30% of annual CO_2 emission. PEAHP plays an important role toward achieving EU low-carbon future.
Materials and Methods. CO_2 emissions and energy consumption data for two-decades in EU was analysed in each SM due to the sectoral report of the European Environment Agency [1]. The database includes inventories of emission and energy consumption from 1990 to 2011 for 26 EU countries. The statistical data was rated, compared and displayed to show the long-term overviews and trends of the CO_2 emission.
Research Results. The CO_2 emission in EU consists of the sum of emissions from each EU SM. It is diverse, particularly, in the European countries. Due to the EU climate framework actions, the CO_2 emissions under the fuel combustion from PEAHP have decreased, whereas the overall energy consumption was increased.
Discussion and Conclusions. To achieve zero-emission policy in EU, it is necessary to further implementing the emission inventory and to identify the CO_2 emission trend. The two-decade data analysis is essential for the development of future scenarios and the adjustment of pathways for more mitigation targets in every single EU country.

Введение. Общественный сектор производства электроэнергии и тепла ЕС (PEAHP) в основном основан на традиционном сжигании топлива и отвечает за 30% ежегодной эмиссии CO_2. PEAHP играет важную роль в достижении будущего низкоуглеродного угля в ЕС.
Материалы и методы. Данные о выбросах CO_2 и потреблении энергии в течение двух десятилетий в ЕС были проанализированы в каждом SM (государство-член ЕС), в соответствии с отраслевым докладом Европейского агентства по окружающей среде [1]. База данных включает инвентаризацию выбросов и потребления энергии с 1990 по 2011 год для 26 стран ЕС. Статистические данные оценивались, сравнивались и отображались, чтобы показать долгосрочные обзоры и тенденции эмиссии CO_2.
Результаты исследования. Количество выброса CO_2 в ЕС состоит из суммы выбросов в каждой SM в ЕС. CO_2 разнообразен, в частности, в европейских странах. Благодаря деятельности ЕС в области климата выбросы CO_2 при сжигании топлива из PEAHP уменьшились, в то время как общее потребление энергии было увеличено.
Обсуждение и заключения. Для достижения нулевого выброса в ЕС необходимо продолжить реализацию инвентаризации выбросов и выявить тенденцию изменения выбросов CO_2. Анализ базы данных за два десятилетия имеет важное значение для разработки будущих сценариев и корректировки способов достижения целей, направленных на минимизацию последствий в каждой отдельно взятой стране ЕС.

Keywords: CO_2 emission, public electricity production, public heat production.

Ключевые слова: CO_2, выбросы, общественное производство электричества, общественное производство тепла.

For citation: E. Niemierka, P. Jadwiszczak, M. A. Sayegh. CO_2 emission trend in public energy sector in EU. Vestnik of DSTU, 2017, vol. 17, no.4, pp. 122–128.

Образец для цитирования: E. Niemierka, P. Jadwiszczak, M. A. Sayegh. CO_2 emission trend in public energy sector in EU. Vestnik of DSTU, 2017, vol. 17, no.4, pp. 122–128.

Introduction. The mitigation of climate change requires reduction or inhibition of greenhouse gases (GHG) emission. Different types of contaminants caused incomparable impact on anthropogenic global warming [2-3]. One of the significant major of European Union (EU) climate policy framework is decreasing CO_2 emission from fuel combustion in public

* The research is done within the frame of the independent R&D.
** E-mail: elzbieta.niemierka@pwr.edu.pl, piotr.jadwiszczak@pwr.edu.pl, ara.sayegh@pwr.edu.pl
*** Работа выполнена в рамках инициативной НИР.

electricity and heat production (PEAHP) sector. PEAHP contains the sum of three emission categories from: electricity plants, combined heat and power plants and heat only plants [4]. The impact of other pollutants than CO_2 from PEAHP is vanishingly small. EU legislation sets mandatory CO_2 emission reduction targets in all EU Member States (MS) [4-7]. PEAHP based on fuel combustion is responsible for a significant part of the annual CO_2 emissions in the EU, which is slightly decreased to around 220 000 kt CO_2, thus it providing nearly 30% of European emissions as it shown in Figure 1 [1]. The CO_2 emission from fuel combustion in PEAHP depends on the both of the consumed conventional energy (constant and amounted about 15 700 PJ) [1] and the CO_2 emission factor (EF), characterized by the technology of generation. In Europe, enlargement of required electricity and heat is caused by growing demand, which are met by alternative or renewable energy sources with a constant PEAHP energy from fossil fuel combustion.

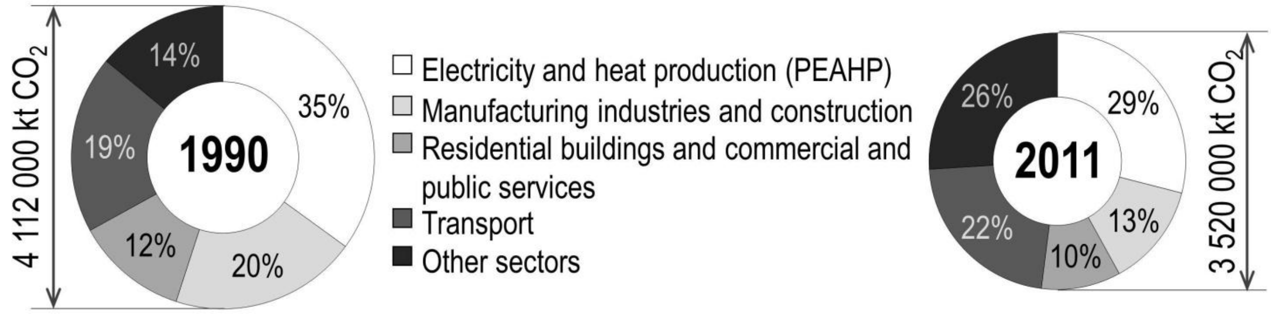


Fig. 1. CO_2 emission changes over the period 1990 to 2011 in EU.

Рис. 1. Изменения выбросов CO_2 в период с 1990 по 2011 гг. в ЕС.

The EU climate framework actions concerned in decreasing the electricity and heat consumption (by essential energy improvements on consumers side e.g. in buildings, energy systems, etc.) and decreasing CO_2 emission factor (EF) per energy unit (e.g. by fuel switching, improvements in generation technology and distribution efficiency, use of cogeneration, renewable sources etc.). There are many other indicators, which will be discussed and analysed in future papers. The PEAHP as a one of the well-controllably and highly-centralized economic sector allows to national and regional scale large improvements. All changes in PEAHP concerned with large efforts and time-consuming processes.

The CO_2 emission trends in European PEAHP. To determine the CO_2 emission trends, European Environment Agency long-term sectoral database was used [1]. The database includes energy consumption and emission statistics over the period from 1990 to 2011 for 26 EU countries. This investigation illustrates the distribution changes overview and the trends of CO_2 emissions in PEAHP for EU over the period from 1990 to 2011. Figure 2 shows statistical analyses of inter-annual variations of CO_2 emissions range in EU countries over the period 1990 to 2011.

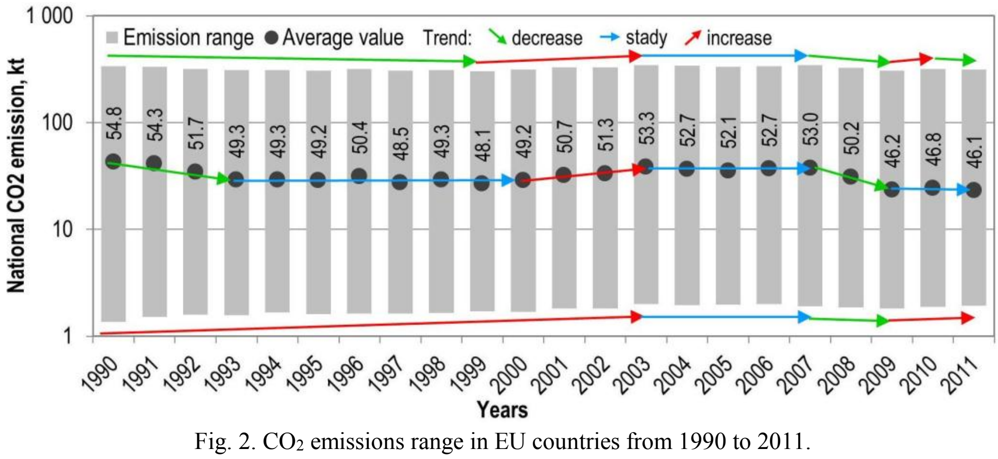


Fig. 2. CO_2 emissions range in EU countries from 1990 to 2011.

Рис. 2. Диапазон выбросов CO_2 в странах ЕС с 1990 по 2011 гг.

The maximum national emissions come from German PEAHP and they are semi stable (over 300 kt CO_2/a) [1]. The variability of maximum could be divided into four periods: stable decrease until 1999, the unfavourable growth over the period 1999 to 2003, the stable steady emission between 2003 to 2007 and slow decrease with fluctuations after 2007. The analysis of obtained results are related to energy consumption and the impurities of PEAHP intensity. The minimum national emissions came from the smaller EU countries like MLT, LVA or CYP with emissions less than 2 kt CO_2/a [1]. The variability of minimum emissions could be divided into four periods: the unfavourable growth until 2003, the slight fluctuations between 2003 to 2007, the steady and stable decrease between 2007 to 2009, small and short-term growth after 2011. These trends are related to the development in countries economy and the increase in energy consumption compared to 1990.

The average national emissions describe the total variability of emissions in all EU countries and illustrates the two-decades trend (from 1990 to 2011) as fluctuating with downward tendency. The six noticeable periods are: significant decline before 1993, stabilization from 1993 to 2000, considerable increase from 2000 to 2003, slightly fluctuating stabilization from 2003 to 2007, dynamic decline from 2007 to 2009 and stabilization until 2011. The CO_2 emission tendency is a complex issue that has been affected by legislation, economy, ecology and technical development. In this reason stabilization of the emission averages can be caused by different reasons, which can be divided into: 1) increase the minima with decreases maxima (1993-1999), 2) stabilization of both minima and maxima (2003-2007) and 3) opposing variation of minima and maxima (2009-2011). The emission variations reflect the political changes of the 90s, the European economic crisis and energy legislations. The stabilized diminishing of EU emissions average is an evident result of EU climate change mitigation actions accompanied by both of economic and ecological development in Europe.

To clarify a situation of PEAHP emission distribution in EU countries the national CO_2 emission factors (EF) were assumed, as a relation indicator between the consumed energy and emitted CO_2 during all cycles of electricity and heat production and distribution. The low values of EF are concerned with clean and environmentally friendly technologies, while high EF are accompanied by old and inefficient technologies of PEAHP. The decreasing trend of EF in Figure 3 shows the technology and fuels improvements in European PEAHP over the period from 1990 to 2011.

Figure 3 shows the favourable downward trend of EF during two-decades in European countries, with the episode of growth since 2008. The trend of minimum EF shows the more significant decline with SWE as the European leader in national EF limitation. The average of EF in EU constantly falls down, it`s around 0,78% per year, which reflects the constant PEAHP development in Europe and right direction of EU`s climate protection framework actions. The decrease of EF standard deviation reflects that all national values tend to bring closer to the diminishing average value of EU national CO_2 emission.

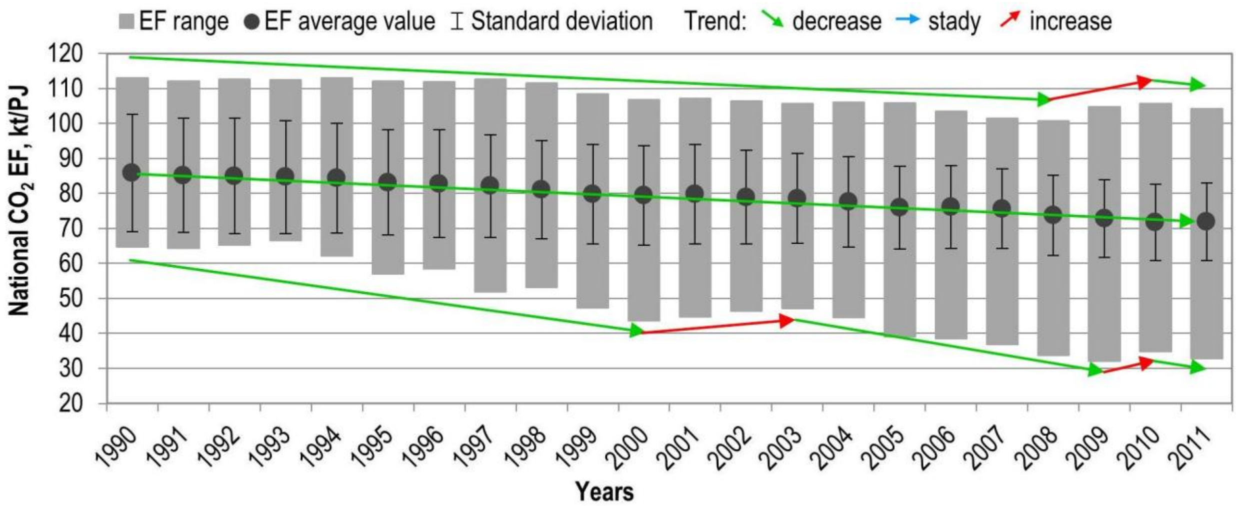
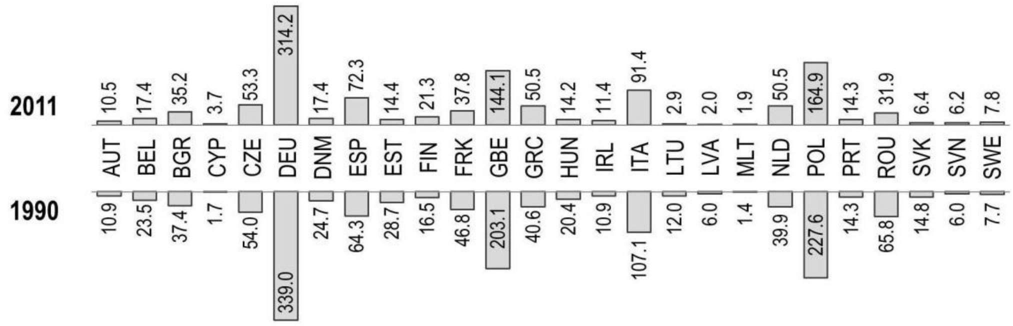


Fig. 3. Changes and trends of national EF in EU countries-from 1990 to 2011.

Рис. 3. Изменения и тенденции EF (коэффициент выбросов) в странах ЕС с 1990 по 2011 гг.

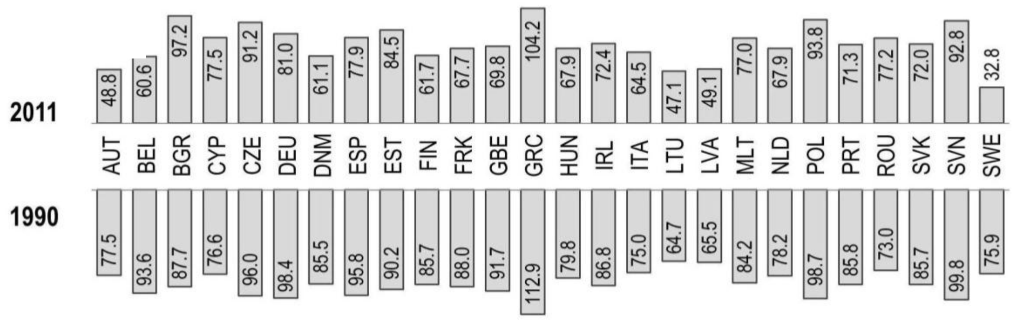
CO_2 emission changes from PEAHP in MS of EU. CO_2 emission in EU consists of the sum of all MS national emissions of EU. To estimate the share of CO_2 emission for each EU country, the distribution value of CO_2 emissions from 1990 to 2011 was analysed as it shown in Figure 4A. The distribution of CO_2 emissions at the national level was very high and achieve from 1.9 (MLT) to 314.1 (DEU) kt CO_2 in 2011 [1]. The top CO_2 emitter countries were DEU, POL, GBE and ITA which emits more than 60% of EU emission and haven't changed their place in the emission classification from 1990. These are large population and area countries with large energy consumption. Table 1 shows the statistic CO_2 emission changes for EU countries from PEAHP between 1990 to 2011. The most favourable change from 12.0 to 2.9 kt CO_2 (76.0%) was observed for LTU, while the most unfavourable change from 1.7 to 3.7 kt CO_2 (-121.6%) was observed for CYP. The CO_2 emission from PEAHP strongly depends on energy consumption, but the changes of both values have not always been analogous. Figure 4B shows the distributions PEAHP energy consumption in EU countries, as a comparison of 1990 and 2011. With reference to the data shown in the Table 1, the most favourable change from 185.6 to 61.1 PJ (67.1%) was observed for LTU, while the most unfavourable change from 101.7 to 236.7 PJ (132.7%) was for SWE. The countries characterized by high CO_2 emission from PEAHP were the countries with energy-intensive economies like (DEU, GBE, POL, etc.). To compare the emissions in EU countries, national emission factor (EF) was assumed, as a relation between the national energy consumption and the national CO_2 emission from PEAHP (Figure 4C).



a)



b)



c)

Fig. 4. *a*) CO_2 emission distribution in each EU SM from 1990 to 2011 (CO_2 kt); *b*) Distribution of public electricity and heat consumption in EU countries from 1990 to 2011 (PJ); *c*) EF distribution in each EU country from 1990 to 2011 (kt CO_2/PJ).

Рис. 4. a) Распределение выбросов CO_2 в каждой стране ЕС с 1990 по 2011 гг. (CO_2 кт); b) Распределение общего потребления электроэнергии и тепла в странах ЕС с 1990 по 2011 гг. (ПДж); c) Распределение факторов выбросов в каждой стране ЕС с 1990 по 2011 гг. (CO_2 кт / ПДж).

The analysis of national EF value in EU each country includes three rating categories of EF values distribution in 1990, in 2011 and the changes of EF values during from 1990 to 2011 as shown in Figure 4C. The EF values in particular EU countries are extremely different both in 1990 and 2011. In basic 1990 year the EF value varies from 64.7 in LTU to 112.9 kt CO_2 /PJ in GRC. In 2011 year the minima value achieved was 32.8 in SWE and maxima 104.2 kt CO_2 /PJ in GRC.

Table 1

Таблица 1

National statistical relative changes of PEAHP emission and energy consumption from 1990 to 2011 in EU countries

Национальные статистические относительные изменения выбросов PEAHP и потребления энергии с 1990 по 2011 гг. в странах ЕС.

Country	**Energy consumption**	**CO_2 emission**	**CO_2 EF**
AUT	52.8%	-3.6%	-37.0%
BEL	14.3%	-26.1%	-35.3%
BGR	-15.0%	-5.7%	10.9%
CYP	119.0%	121.6%	1.2%
CZE	3.8%	-1.4%	-5.0%
DEU	12.6%	-7.3%	-17.7%

Country	Energy consumption	CO_2 emission	CO_2 EF
DNM	-1.5%	-29.7%	-28.6%
ESP	38.2%	12.3%	-18.7%
EST	-46.4%	-49.7%	-6.3%
FIN	79.4%	29.2%	-28.0%
FRK	4.9%	-19.3%	-23.1%
GBE	-6.8%	-29.1%	-23.9%
GRC	34.8%	24.3%	-7.7%
HUN	-18.5%	-30.7%	-15.0%
IRL	25.8%	5.0%	-16.6%
ITA	-0.8%	-14.7%	-14.0%
LTU	-67.1%	-76.0%	-27.2%
LVA	-55.7%	-66.8%	-25.1%
MLT	54.6%	41.3%	-8.6%
NLD	45.7%	26.5%	-13.2%
POL	-23.8%	-27.5%	-4.9%
PRT	19.8%	-0.4%	-16.9%
ROU	-54.1%	-51.5%	5.8%
SVK	-48.9%	-57.0%	-15.9%
SVN	11.8%	3.9%	-7.0%
SWE	132.7%	0.5%	-56.8%

The most significant national EF changes were characterised by 10.9% increase in BGR (from 88.7 to 97.2 kt CO_2/PJ) and by 56.8% decrease in SWE (from 75.9 to 32.8 kt CO_2/PJ). Table 1 shows the detailed changes of EF in each EU country. Such variations are due to different levels of national PEAHP technology, EF baseline and country economic potential.

Changes of CO_2 emission profiles from PEAHP in each EU country. The national CO_2 emissions are dynamic values, which depend on time, political, economic, technology progress and national legislation. On the base of European Environment Agency data [1] 26 illustrative profiles of CO_2 emission and energy consumption from EU each national PEAHP were provided as shown in Figure 5. The line in each profile represents CO_2 emission and the grey area expresses the energy consumption from 1990 to 2011. All presented national profiles start at theoretical point which join the emission and energy consumption and illustrate the base proportions in 1990.

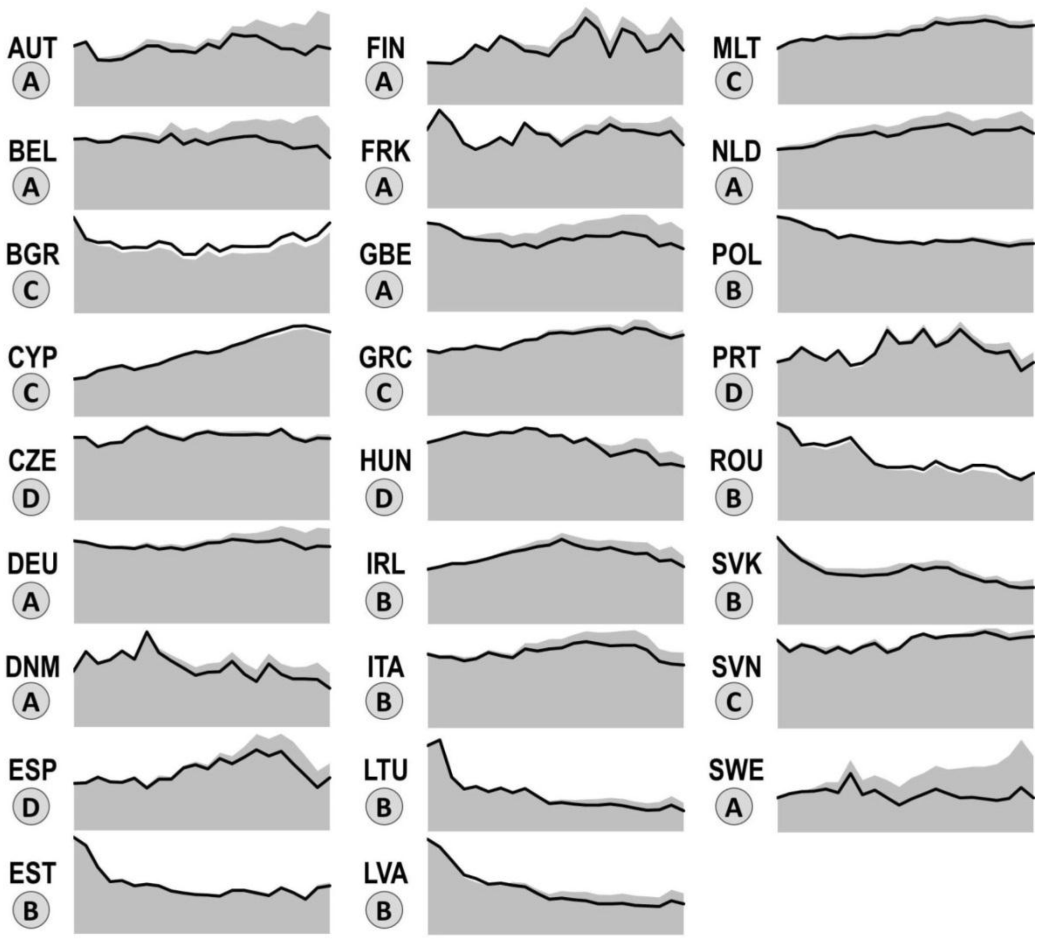


Fig. 5. Illustrative profiles of CO_2 emissions and energy consumption from PEAHP in the period from 1990 to 2011.

Рис. 5. Иллюстративные профили выбросов CO_2 и потребления энергии от PEAHP в период с 1990 по 2011 гг.

The presented results indicate the strong dependency of national CO_2 emission and PEAHP energy consumption, which can be classified into four groups as it shown in Table 2. The group A includes the countries where the CO_2 emissions decrease with increasing energy consumption. In group B the emissions and energy consumptions are decreasing simultaneously. Group C is characterized by increased emissions and energy consumption simultaneously. Group D includes MS of EU with stable emissions and energy consumption or with CO_2 reduction due to improvements in the recent years.

Table 2

Таблица 2

Grouping EU countries due to PEAHP emissions and energy consumptions

Группировка стран ЕС из-за выбросов PEAHP и потребления энергии

Group	CO_2 emission	Energy consumption	EU Countries
A	decrease	increase	AUT, BEL, DEU, DNM, FIN, FRK, GBE, NLD, SWE
B	decrease	decrease	EST, ITA, IRL, LTU, LVA, POL, ROU, SVK
C	increase	increase	BGR, CYP, GRC, MLT, SVN
D	stable or improvement		stable: CZE or improvements in recent years: ESP, HUN, PRT

The groups A and B present the positive trends in national PEAHP and economy. According to EU climate legislation the CO_2 reduce actions do not hamper the national economic growth without energy prices increasing [4,7].Classified as category C countries consume increasing value of energy from fuel combustion with slightly improvements in PEAHP. At the current stage in these countries the economic development seems to be the major target than environmental issue.

The analysis show positive tendency in European PEAHP. CO_2 emissions from public energy sector are successively reduced by improvements in energy production technologies and reduce of fuel combustion.

Conclusions. The assessment and classification of environmental impact of public electricity and heat production sector in EU is a complex issue. The PEAHP from conventional fuel combustion is still responsible for a significant portion of annual CO_2 emission in EU. Since 1990 the EU climate legislations and framework actions let to decrease CO_2 emissions from fuel combustion in PEAHP, with slightly rising in overall energy consumption in Europe. This has been achieved in two main ways: first by reduction of energy consumption, second by improvement in PEAHP technologies. The EU climate policy takes into account the countries potential and sets adequate ecological goals and environmental targets. On the one hand, this leads to changes in pace and size of CO_2 emissions in EU individual countries and on the other hand it accelerates the progress of environmental friendly actions in Europe. Environment legislations are the cornerstone of the EU's strategy to improve the climate and energy economy.

The ”top four” countries with the largest national CO_2 emissions from PEAHP haven’t changed from 1990 to 2011. There are also significant relative emission changes e.g. CYP, where the CO_2 emissions increased over twice in the same period, while LTU decreased CO_2 emission over three times for the same period.

The average CO_2 emission in Europe has a downward trend. In all EU countries the national CO_2 emissions have changed: sometimes it has fallen and in others has even risen.

The availability of data and multi-range dependencies shape the image of CO_2 emissions from European and national PEAHP. Regular monitoring of European national and regional emission changes allows the evaluation and correction of the CO_2 reduction scenarios and actions to achieve near zero-carbon PEAHP.

References

1. European Environment Agency, National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism, 2013, 15p.

2. Ogden J., Anderson L., Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers. Part 2, Institute of Transportation Studies, University of California, Davis (ITS), 2011, pp. 133-169.

3. Intergovernmental Panel on Climate Change, Climate Change 2014. Synthesis Report, 2014, 30p.

4. Regulation (EU) No. 525/2013 of the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision, No. 280/2004/EC, 13p.

5. European Commission, Climate strategies & targets. Available at: https://ec.europa.eu/clima/policies/strategies_en (accessed: 12.09.2017)

6. European Environment Agency, Greenhouse gas emission trends, 2017. Available at: https://www.eea.europa.eu (accessed: 12.09.2017)

7. W. J. Antholis. The Good, the Bad, and the Ugly: EU-U.S. Cooperation on Climate Change, 2009. Available at: www.brookings.edu (accessed: 12.09.2017)

Библиографический список

1. European Environment Agency, National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism, 2013, 15p.
2. Ogden J., Anderson L., Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers. Part 2, Institute of Transportation Studies, University of California, Davis (ITS), 2011, pp. 133-169.
3. Intergovernmental Panel on Climate Change, Climate Change 2014. Synthesis Report, 2014, 30p.
4. Regulation (EU) No. 525/2013 of the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision, No. 280/2004/EC, 13p.
5. European Commission, Climate strategies & targets. Available at: https://ec.europa.eu/clima/policies/strategies_en (accessed: 12.09.2017)
6. European Environment Agency, Greenhouse gas emission trends, 2017. Available at: https://www.eea.europa.eu (accessed: 12.09.2017)
7. W. J. Antholis. The Good, the Bad, and the Ugly: EU-U.S. Cooperation on Climate Change, 2009. Available at: www.brookings.edu (accessed: 12.09.2017)

Received 15.07.2017
Submitted 16.07.2017
Scheduled in the issue 20.09.2017

Поступила в редакцию 15.07.2017
Сдана в редакцию 16.07.2017
Запланирована в номер 20.09.2017

Authors:

Niemierka, Elżbieta,
MSc, Wrocław University of Science and Technology (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
elzbieta.niemierka@pwr.edu.pl

Jadwiszczak, Piotr,
Wrocław University of Science and Technology (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
piotr.jadwiszczak@pwr.edu.pl

Sayegh, Marderos Ara,
Wrocław University of Science and Technology (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
ara.sayegh@pwr.edu.pl

Об авторах:

Ниемарка Эльжбета,
Магистр гуманитарных наук, Вроцлавская политехника (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
elzbieta.niemierka@pwr.edu.pl

Ядвищак Петр,
Вроцлавская политехника (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
piotr.jadwiszczak@pwr.edu.pl

Саег Мардирос Ара,
Вроцлавская политехника (Poland, 50-373, Wroclaw, ul. Norwida 4/6 (building C-6)
ara.sayegh@pwr.edu.pl